PROJECT REPORT ON

STUDIES ON TREATMENT OF SUGAR INDUSTRY EFFLUENT USING INVERSE FLUIDISED BED BIOREACTOR

A Report Submitted In partial fulfilment of the requirements of B.Tech

Chemical Engineering

Submitted by

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CERTIFICATE

This is to certify that the project report entitled **"Studies On Treatment Of Sugar Industry Effluent Using Inverse Fluidised Bed Bioreactor"** submitted by **Banka Bihari Praharaj** (110CH0417) in partial fulfilment of the requirements for the award of B.Tech Degree in Chemical Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the report has not been submitted to any other University/Institute for the award of any Degree.

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ABSTRACT

Treatment of effluent of sugar industry is carried out by inverse fluidized bed. Different components of effluent like chemical oxygen demand (COD), biochemical oxygen demand (BOD) and pH have been measured by varying different parameter such as concentration, time of fluidization. The growth of microorganism w.r.t. different parameter has been noted. COD, BOD and pH are observed to decrease with decreasing concentration of the solution. Again values of different output parameters (BOD, COD and pH) are observed to be reduced with increasing timing in an inverse fluidized bed. Microorganisms are allowed to grow and steady state was observed same microbes were transferred to inverse fluidized bed for studying the effect of parameters on its growth. Microorganisms are observed to be grown on the surface of polypropylene beads by producing a biofilm. The observed reduction in COD, BOD and pH indicate the suitability for the application of inverse fluidised bed for waste water treatment for any industry.

Keywords: Inverse fluidization; COD reduction; BOD and pH analysis

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CHAPTER 1

INTRODUCTION

Fluidization is a technique in which solid particle behaves like fluid when come in contact with liquid, gas or both. At the time of fluidization there are two force acting on the solid particle one is gravitational force and other one is fluid drag force.

1.1:-INVERSE FLUIDIZATION

When the direction of liquid and gas is opposite in direction the fluidization technique is called inverse fluidization. This method is useful when the solid particle density is lower than that of liquid. We can achieve fluidization by passing gas from the bottom and liquid from the top side. Inverse fluidization is of two type two phase or three phase inverse fluidization. In two phase inverse fluidization; fluidization achieve with liquid and solid but in three phase fluidization gas, liquid and solid are needed to fluidised the bed.

Liquid fluidization draw large attention because it is useful in many new fields like biochemical field and in treatment of industrial effluents. This type of fluidization help us when the particle density is higher than that of liquid by passing liquid from the bottom. Now a day's inverse fluidization is drawing more attention because of some advantages of this over fluidization like we can control the bio film thickness in biochemical processing unit. Here the velocity of fluidization is low so energy consumption is low and solid attrition is also low, ease of fluidization in case of power failure and the mass transfer rates are high.

1.2:-ADVANTAGES OF INVERSE FLUIDISATION PROCESS

We can easily do treatment of effluent of different industries like wine, sugar, paper using inverse fluidization technique because this process is easy to handle, the cost is low, the energy consumption is low and the efficiency is more than that of normal fluidization technique. The advantages of this over normal fluidization are the gas holdups are large, less energy required because of low fluid velocity, the attrition of solid particle is low so easy in the fluidization process, the mass transfer rates are high and the fluidization can be carried out without any problem in case of power failure.

1.3:-APPLICATION OF INVERSE FLUIDIZATION

1. These are very much useful in treatment of industrial effluent.
2. These are useful in biotechnology field in the immobilization of biocatalyst reactor.
3. Control of biofilm thickness and ease of re-fluidization in case of power failure in inverse fluidization. This helps in the treatment of effluent of wine industry.
4. With the development of fluidized bed, coal combustion and the recent interest in the use of fluidized beds for waste utilization and for dry solids separation, the potential applications of multi-component fluidized beds are on the rise. It is because; the fluidized particles though uniform in size at beginning, may change due to the attrition, coalescence and chemical reaction, thereby affecting the quality of fluidization.

1.4:-OBJECTIVE

1. Study on COD, BOD, and pH of the effluent of the sugar industry by varying different parameters like concentration, time of fluidization and plot the responses.

2. To compare the performance of inverse fluidised bed with the published data.

1.5:-LITEREATURE REVIEW

Inverse fluidization is use for the treatment of sewage and waste waters. Bacteria grows in the chemically inter media and break down the sewage or waste water. But the bacteria has to grow perfectly in the column producing a bio film on the surface of the solid particle used and helps in the breaking sewage or waste water. We can decrease the value of liquid measuring pollutants to a greater level by measuring the COD, BOD, TSS and again the waste water can be reused. In this treatment microorganisms are playing vital role so it is important to monitor the amount and quality of microorganism in the bed. There are many microorganism which helps in the treatment of a particular waste water. In case of treatment of effluent of sugar industry Staphylococcus aureus gives better results in removing the pollutants.

1.6:-PREVIOUS STUDIES:

- **Gomez et al. (2006)** studied the phenol removal in a laboratory scale fluidized bed reactor by immobilized derivatives of soybean peroxide. The effect of different variables on the process is also studied and a model is setup based on the experimental results that shows the behaviour of system in both steady and transient state. He consider the fluidized bed reactor as the plug flow reactor in series with an ideal mixer and obeys a kinetic law based on the observed external mass transfer resistances in order to work out the process rate.

- **Sokol & korpal (2006)** investigated in the inverse fluidized bed bio film reactor (IFBBR) in which polypropylene particles of density 910 kg/m3 were fluidized by an upward co-current flow of gas and liquid. Measurements of chemical oxygen demand (COD) versus residence time *t* are performed for various ratios of settled bed volume to bioreactor volume (*V*b/*V*R) and air velocities *u* to determine the optimal operating parameters for a reactor, that is, the values of (*V*b/*V*R), *u* and *t* for which the largest reduction in COD occurred. The biomass loading in a reactor depended on the ratio (*V*b/*V*R) and an air velocity *u*.
- **Sowmeyan & Swaminathan (2007)** worked to evaluate the feasibility of an inverse fluidized bed reactor for the anaerobic digestion of distillery effluent, with a carrier material that allows low energy requirements for fluidization, providing also a good surface for biomass attachment and development. Inverse fluidization particles having specific gravity less than one are carried out in the reactor.
- Removal of COD is about 70% of industrial effluent by inverse fluidized bed (**Sokol, 1994**).

CHAPTER 2

MATERIALS AND METHOD

Different types of materials and different processes are carried out for the treatment of effluent. The methods which are used for the determining of different parameters like COD, BOD, pH.

2.1:-MATERIALS REQUIRED

1. Fluid- air and effluent
2. Solid- polypropylene beads of 6 mm diameter
3. Microorganism- *staphylococcus aureus*

Different setup for different mode of fluidization 2 phase or 3 phase. Two phase inverse fluidization is carried out by only the flow of liquid. Three phase inverse fluidization can be carried out in two ways i.e. continuous mode and batch mode. In batch mode solid particles fluidized by passing only gas from the bottom there is no net flow of liquid occur. But in continuous mode both liquid and gas contribute in the fluidization of solid particles. In batch mode waste water is stored in the column first and then gas is passes from the bottom for fluidization to occur. Measurement of different parameters are done by taking some amount of sample from the discharge end and tests are carried out. In case of continuous mode simultaneously there will be liquid flow and gas flow.

2.2:-EXPERIMENTAL SET UP

The column was made of Perspex and had the dimension of 100 mm internal diameter with a maximum height of 1240 mm and a wall thickness of 3 mm. The column consisted of three sections, namely,

1. **Conical liquid distribution section:**

The larger diameter of this section is 10 cm which is same as of column diameter and the smaller diameter is 3 cm. The angle of cone is 30^{o}.The distributor is also kept at the top of the column. Ball valves are there to control the incoming water low rate.

2. **Test section:**

The height of this section is 100cm and there are 10 number of tapings with a gap of 10 cm. The pressure tapings are connected with manometers with help of pipes.

3. **Conical liquid discharge section:**

This section consists exit outlet for the water, at the bottom of the column another distributors given to prevent the particles from escaping the bed. This distributor also works as sparger of air .A non-returning control valve is there to let the air in.

4. Five number of manometers (1 metre) are there to measure the bed pressure drop. These manometers are filled with carbon tetra chloride.

Fig. - 2.1:-Experimental setup

At the top of the column there is one conical head distributor designed such that there will be uniform distribution of liquid across the column. A wire gauge was provided at the bottom just above the liquid discharge section to ensure no solid particle should discharge with liquid. One wire gauge is placed at the top to ensure that no solid particle should escape from the top of the column. Liquid is to be pump to the top of the column through rota meters and solids are fed in to the column from the top. Air from the compressor goes to the storage tank from where we supply air to the column from the bottom of the column. We can control the flow rate of air from the valve provided in the storage tank. There are pressure tapping with an interval of 10 cm which are connected to the carbon tetrachloride manometer. The liquid discharge section is connected with pipe and discharged to the reservoir. In case of continuous mode again that discharge liquid is fed to the column from the top. A valve is there to control the flow rate of discharge liquid.

2.3:-PARTS OF SETUP

1. The column is of 1024mm height and the diameter is 100mm with a thickness of 3mm and material of construction is perplex.
2. A pump is used to pump the water from the reservoir to the column.
3. A water rotameter of 0-100 LPM is used to measure the flow rate of liquid pumped from the reservoir.
4. Air rotameter of 0-1000 LPH is used to measure the flow rate of air coming from the storage tank to the bottom of the column.
5. Five manometer of carbon tetrachloride of 1 meter length is used for the measurement of pressure drop across the bed.
6. On the top and bottom part of the column circular pitch distributor of different pitch diameter are used for proper distribution of air and water in the column.

2.4:-METHODS

Methods used for calculating COD, BOD and procedure of the experiment are explain below.

2.4.1:-Chemical oxygen demand (COD)

The COD test is used for measuring the amount of organic pollutants in water. They determine the amount of organic compound present in surface water like effluent, waste water. This helps in knowing the quality of water and express in mg/L; which is mg of oxygen consumed per litre of solution. In other words this measures the material present in the waste water can be oxidised in presence of strong oxidizing chemical. This is a rough measure of pollution level in waste water because test carried out rapidly.

Following formula is used for determining COD

COD (mg/L) = (A-B)*1000*8*N/Vo **(1)**

Where A = ml FAS used for blank

B = ml. FAS used for sample

N=normality of FAS

Vo=mL of sample

2.4.1.1: **Measurement of COD**

(A) Principle

The organic matter present in the sample produce CO_2 and H_2O by oxidizing completely with $K_2Cr_2O_7$ in the presence of H_2SO_4, $AgSO_4$ and $HgSO_4$. The sample is refluxed with a known amount of potassium dichromate ($K_2Cr_2O_7$) in the sulphuric acid medium and the excess potassium dichromate ($K_2Cr_2O_7$) is determined by titration against ferrous ammonium sulphate, using ferroin as an indicator. The dichromate consumed by the sample is equivalent to the amount of O_2 required to oxidize the organic matter.

(B) Chemical required

1. Potassium dichromate
2. Sulphuric acid
3. Ferrous ammonium sulphate
4. Silver sulphate
5. Mercury sulphate
6. Ferroin indicator
7. Organic free distilled water

2.4.2:-Biochemical oxygen demand (BOD)

BOD of waste water is the amount of oxygen required for the biological decomposition of organic matter on a standard period of time and temperature. The standard time is taken to be 5 days and the standard temperature is 20^{o}C.

(A) Principle

The sample is filled in an airtight bottle and incubated at specific temperature for 5 days. The dissolved oxygen (DO) content of the sample is determined before and after five days of incubation at 20°C and the BOD is calculated from the difference between initial and final DO.

Following formula is used for the determination of BOD

$$\mathbf{BOD} = (\boldsymbol{Do - D5}) * (\frac{\boldsymbol{volume\ of\ dilution}}{\boldsymbol{volume\ of\ sample}}) \quad \textbf{(2)}$$

Where Do-initial D.O. of sample

D_5-D.O. at the end of 5 days of sample

(B) Reagents required

1. Manganous Sulphate Solution
2. Alkaline Iodide Sodium Azide Solution
3. Sodium Thiosulphate stock solution
4. Starch Indicator
5. Sulphuric Acid

2.4.3:-PROCEDURE

1. Solid particle of the particular size and density loaded to the column to a particular bed height.
2. Effluent was mix with water to get the desired concentration.
3. The solution is fed to the column to a particular height.
4. Microbes are allowed to grow on the beads surface.
5. Air was passed from the bottom to carry out the fluidization.
6. After certain time interval sample was taken from the discharge section and performed the required test to measure different parameters.

2.4.4:-MICROORGANISM

Here *staphylococcus aureus* microorganism was selected for the treatment of sugar industry. This gives better degradation of compound present in the sugar industry effluents. This bacteria cause dieses to many animal including human being. We can found this on the skin and throat pipe of human being. The main dieses cause due to this bacteria is skin dieses. They grow in a wide range of pH i.e. 4.3 to 9.2 and gives better result in between 7.3-8.2.

2.4.5:-INOCULUM PREPARATION

The microbial species of *staphylococcus aureus* is taken from the solidified slant culture. Then nutrient broth is prepared which is readymade available. 3.25 gm of nutrient was added to 250 ml of distilled water and the solution is checked for pH=7.It was autoclaved at 121^0 c for 20 min. & then it was cooled. Microbes are extracted from the mother culture by swapping method through inoculums loop and was mixed to the nutrient solution. Then it is kept at laminar flow chamber at 30^0 c temp, 120 rpm and incubated for around 1 day. Again to make the volume up to 1 litre the procedure is repeated. This time the 250 ml. incubated solution is take as mother culture.

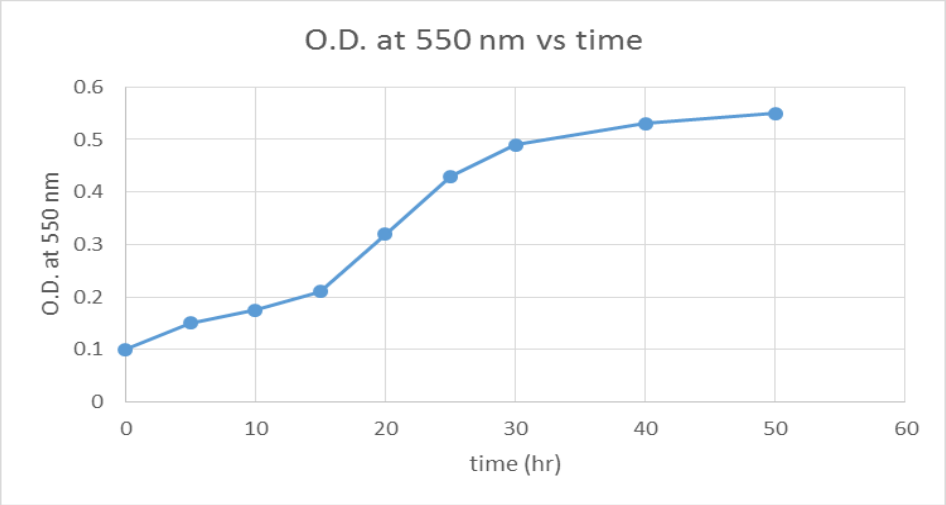

Fig. - 2.2: Growth of microorganism with time

CHAPTER 3

RESULTS AND DISCUSSION

Observation for the COD, BOD and pH with variation of different parameters are listed below and their responses are plotted in different graphs.

3.1: COD VARIATION WITH CONCENTRATION

(A) 100% concentration solution (100% effluent provided by the industry)

Titration readings noted for COD with 100% concentration of solution are listed in TABLE 3.1.

TABLE NO. 3.1: Titration for COD at 100% concentration

Sl no	Sample	Volume of sample (ml)	Burette reading (ml)		Volume of 0.1 N FAS (ml)
			Initial	Final	
1	Blank	2.5	0	14.1	14.1
2	Sample	2.5	14.1	21.7	7.6
3	Sample	2.5	21.7	29.3	7.6

Sample Calculation:

From equation 1 it can be written as

$$\textbf{COD (mg/L) = (A-B)*1000*8*N/Vo}$$

Where, A=14.1

B=7.6

V_o =2.5

N=0.1

COD (mg/L) = **2080**

(B) 50% concentration solution (50% effluent + 50% water)

Titration readings noted for COD with 50% concentration of solution (50% effluent + 50% water) are listed in TABLE 3.2.

TABLE NO. 3.2: Titration for COD at 50% concentration

Sl no	Sample	Volume of sample (ml)	Burette reading (ml)		Volume of 0.1 N FAS (ml)
			Initial	Final	
1	Blank	2.5	0	14.1	14.1
2	Sample	2.5	14.1	23.4	9.3
3	Sample	2.5	23.4	32.7	9.3

Where, A=14.1

B=9.3

V_O=2.5

N=0.1

COD (mg/L) = **1536**

(C) 25% concentration solution (25% effluent + 75% water)

Titration readings noted for COD with 25% concentration of solution (25% effluent + 75% water) are listed in TABLE 3.3.

TABLE NO. 3.3: Titration for COD at 25% concentration

Sl no	Sample	Volume of sample (ml)	Burette reading (ml)		Volume of 0.1 N FAS (ml)
			Initial	Final	
1	Blank	2.5	0	14.1	14.1
2	Sample	2.5	14.1	25.4	11.3
3	Sample	2.5	25.4	36.7	11.3

Where, A=14.1

B=11.3

V_o=2.5

N=0.1

COD (mg/L) =**896**

Observation table for variation of COD with concentration is listed in TABLE NO. 3.4 and response is plotted in fig no: 3.1

TABLE NO. 3.4: Variation of COD with concentration

Sl no	Concentration (% v/v)	COD (mg/L)
1	100	2080
2	50	1536
3	25	896

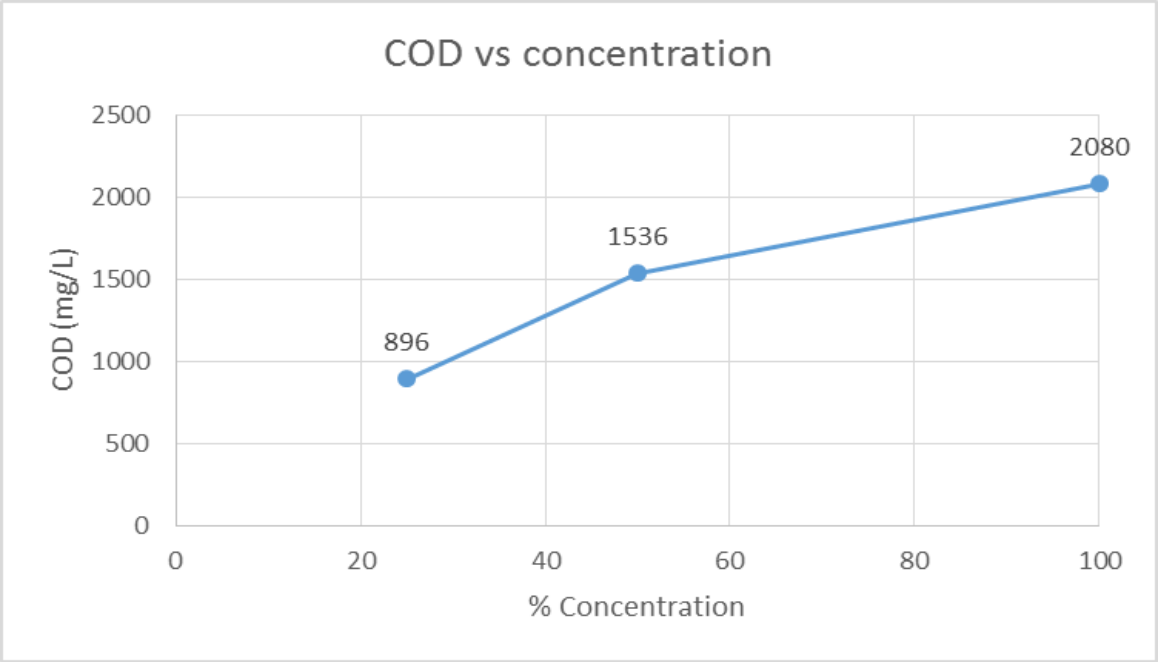

Fig. - 3.1: Response of COD with concentration

3.2: BOD VARIATION WITH CONCENTRATION

(A) 100% concentration (100% concentration of effluent provided by industry)

Titration readings noted for BOD with 100% concentration of solution are listed in TABLE 3.5.

TABLE NO. 3.5: Titration for BOD at 100% concentration

Sl no	DAY NUMBER	Volume of dilution (ml)	Burette reading (ml)		Difference (final-initial)	Dissolved oxygen (mg/L)
			Initial	Final		
1	0	200	0	22.7	22.7	22.7
2	0	200	22.7	45.4	22.7	22.7
3	5	200	0	4.5	4.5	4.5
4	5	200	4.5	9.0	4.5	4.5

Sample Calculation

From equation 2 it can be written as

$$\textbf{BOD} = (\boldsymbol{Do - D5}) * (\frac{\boldsymbol{volume\ of\ dilution}}{\boldsymbol{volume\ of\ sample}})$$

Where, Do = 22.7 mg/L

D5 = 4.5 mg/L

Volume of dilution = 200 ml

Volume of sample = 5 ml

BOD = **728 mg/L**

(B) 50% concentration solution (50% effluent + 50% water)

Titration readings noted for BOD with 50% concentration of solution (50% effluent + 50% water) are listed in TABLE 3.6.

TABLE NO. 3.6: Titration for BOD at 50% concentration

Sl no	DAY NUMBER	Volume of dilution (ml)	Burette reading (ml)		Difference (final-initial)	Dissolved oxygen (mg/L)
			Initial	Final		
1	**0**	**200**	**0**	**29.2**	**29.2**	**29.2**
2	**0**	**200**	**29.2**	**58.4**	**29.2**	**29.2**
3	**5**	**200**	**0**	**15.9**	**13.3**	**15.9**
4	**5**	**200**	**15.9**	**31.8**	**13.3**	**15.9**

Where, Do = 29.2mg/L

D5 = 13.3 mg/L

Volume of dilution = 200 ml

Volume of sample = 5 ml

BOD = **532 mg/L**

(C) 25% concentration solution (25% effluent + 75% water)

Titration readings noted for BOD with 25% concentration of solution (25% effluent + 75% water) are listed in TABLE 3.7.

TABLE NO. 3.7: Titration for BOD at 25% concentration

Sl no	DAY NUMBER	Volume of sample (ml)	Burette reading (ml)		Difference (final-initial)	Dissolved oxygen (mg/L)
			Initial	Final		
1	**0**	**200**	**0**	**31.2**	**31.2**	**31.2**
2	**0**	**200**	**31.2**	**62.4**	**31.2**	**31.2**
3	**5**	**200**	**0**	**23.1**	**23.1**	**23.1**
4	**5**	**200**	**23.1**	**46.2**	**23.1**	**23.1**

Where, Do = 31.2 mg/L

D5 = 23.1 mg/L

Volume of dilution = 200 ml

Volume of sample = 5 ml

BOD = **324 mg/L**

Observation table for variation of BOD with concentration is listed in TABLE NO. 3.8 and response is plotted in fig no: 3.2

TABLE NO. 3.8: Variation of BOD with concentration

Sl no	Concentration (% v/v)	BOD (mg/L)
1	100	728
2	50	532
3	25	324

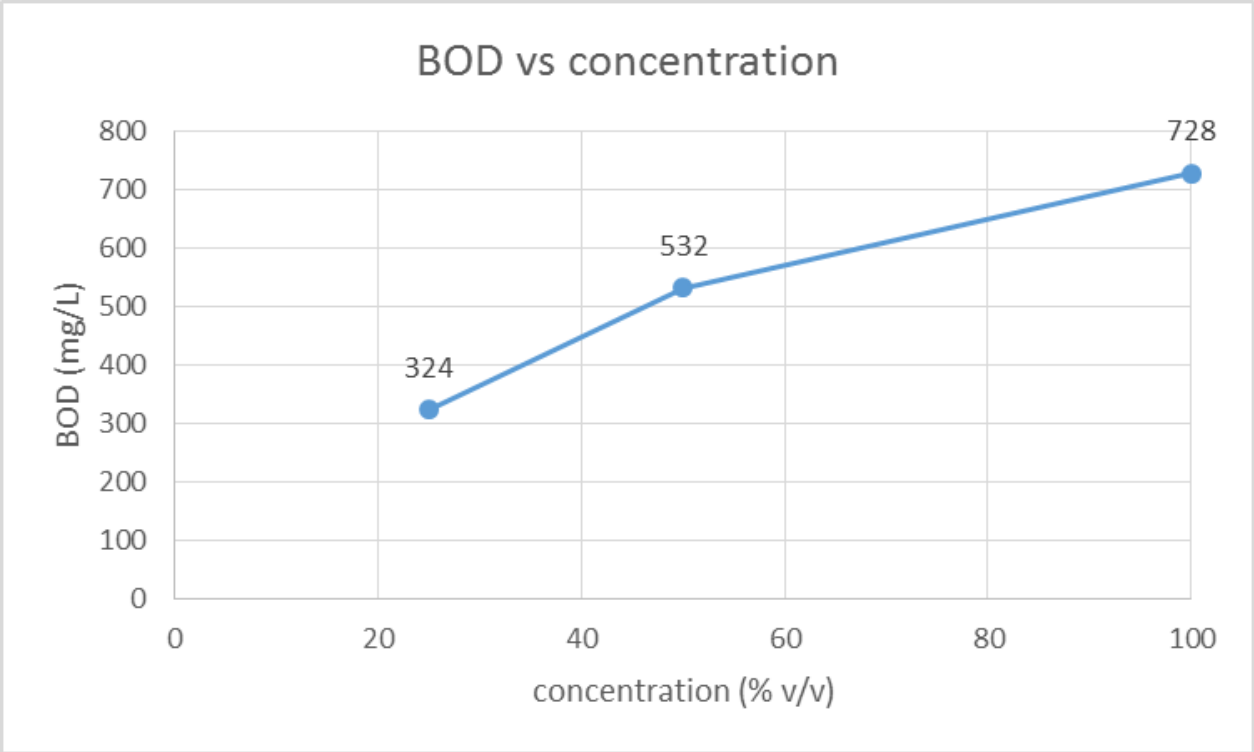

Fig. - 3.2: Response of BOD with concentration

3.3: VARIATION OF pH WITH CONCENTRATION

Observation table for variation of pH with concentration is listed in TABLE NO. 3.9 and response is plotted in fig no: 3.3

TABLE NO. 3.9: Variation of pH with concentration

Sl no	Concentration(% v/v)	pH
1	100	7.9
2	50	7.6
3	25	7.4

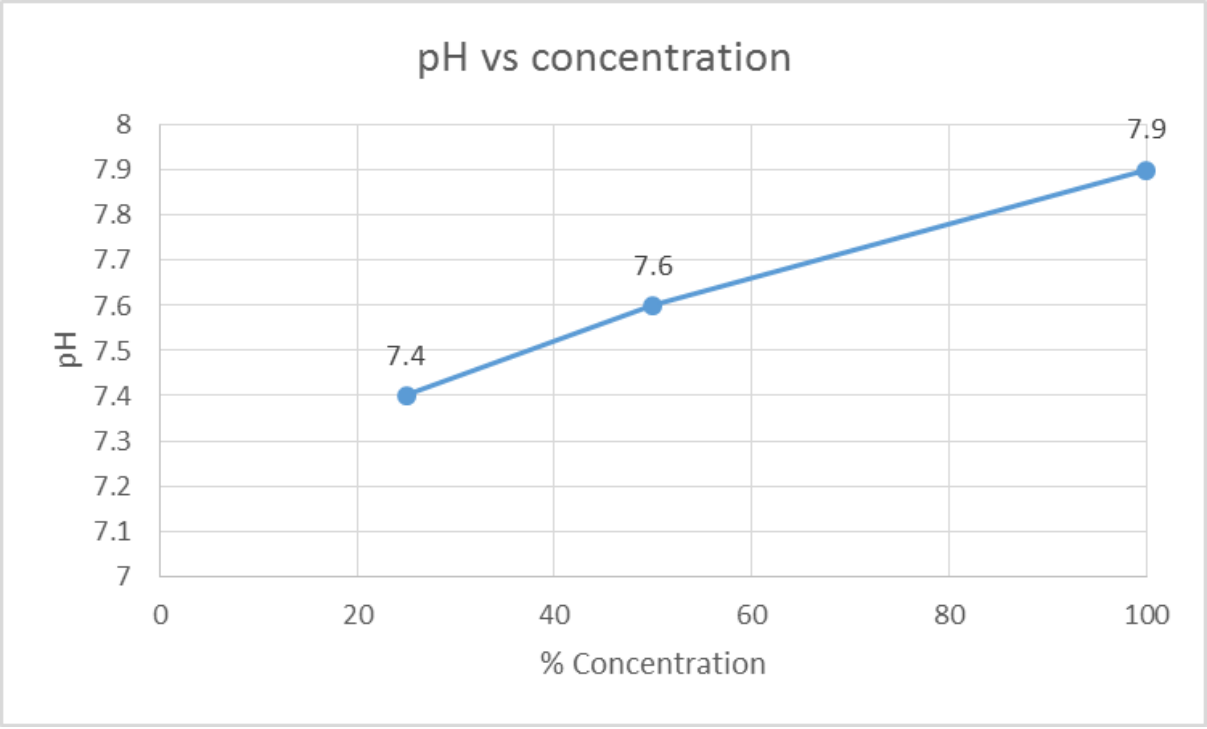

Fig. - 3.3: Response of pH with concentration

TABLE NO. 3.10: For 100 % concentration of effluent the parameters are listed below

Sl no	Parameters	Observed value of parameter	Standard value of parameter
1	Colour	Brown	Colourless
2	Odour	Unpleasant	Odourless
3	COD	2080 mg/L	250 mg/L
4	BOD	728 mg/L	30 mg/L
5	pH	8.2	5.5-9

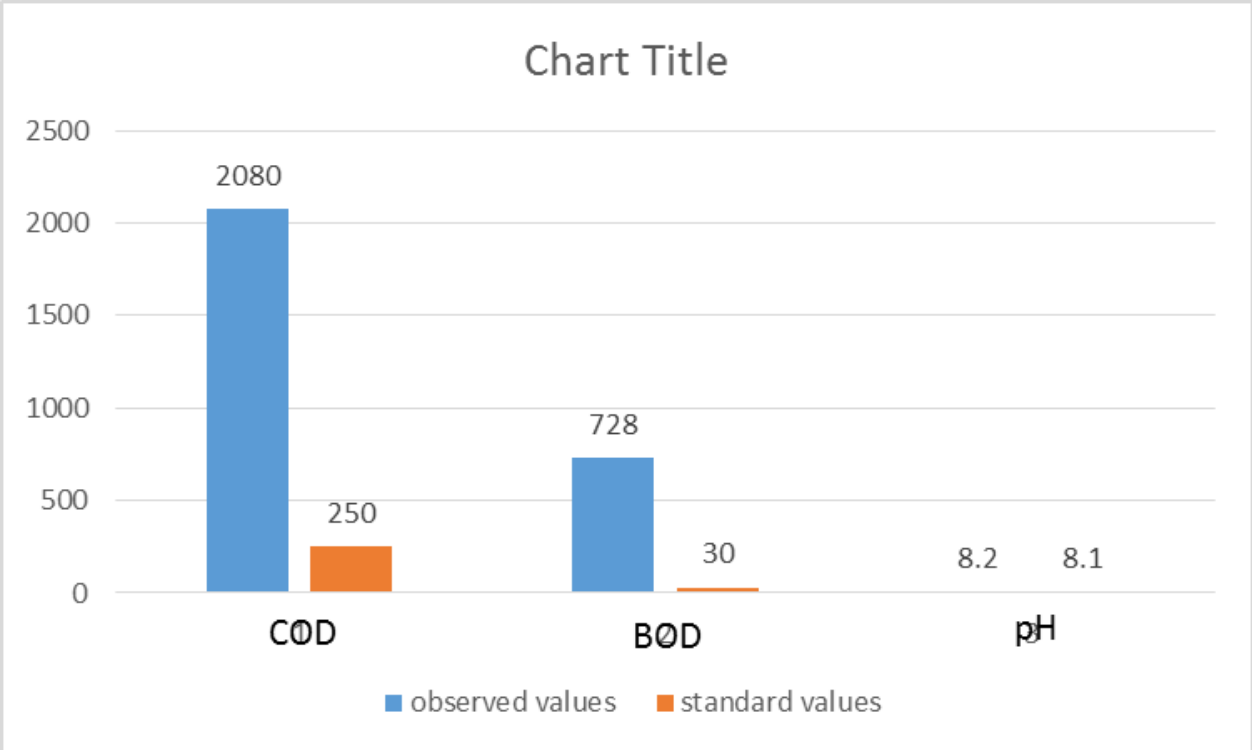

Fig. - 3.4: Observed parameter vs standard parameter

When the fluidized bed has started at a time interval sample were taken from the discharge line and the required tests are performed.

COD, BOD and pH of the solutions which are the measures of pollution level of the effluent were measured against time.

3.4: VARIATION OF COD WITH TIME DURING FLUIDIZATION

Observed values of COD with time during fluidization is listed in TABLE 3.11 and response is plotted in Fig no: 3.5

TABLE NO. 3.11: Variation of COD with time during fluidization

Time (hr)	COD (mg/L)
0	896
15	864
30	800
48	768

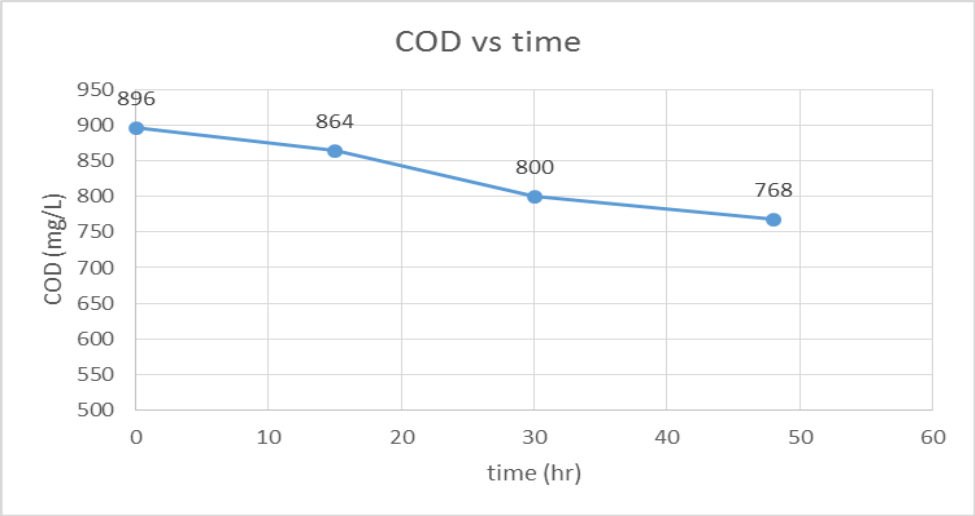

Fig. - 3.5: Variation of COD with time at during fluidization

3.5: VARIATION OF BOD WITH TIME DURING FLUIDIZATION

Observed values of BOD with time during fluidization is listed in TABLE 3.12 and response is plotted in Fig no: 3.6

TABLE NO. 3.12: Variation of BOD with time during fluidization

Time (hr)	BOD (mg/L)
0	324
15	312
30	288
48	276

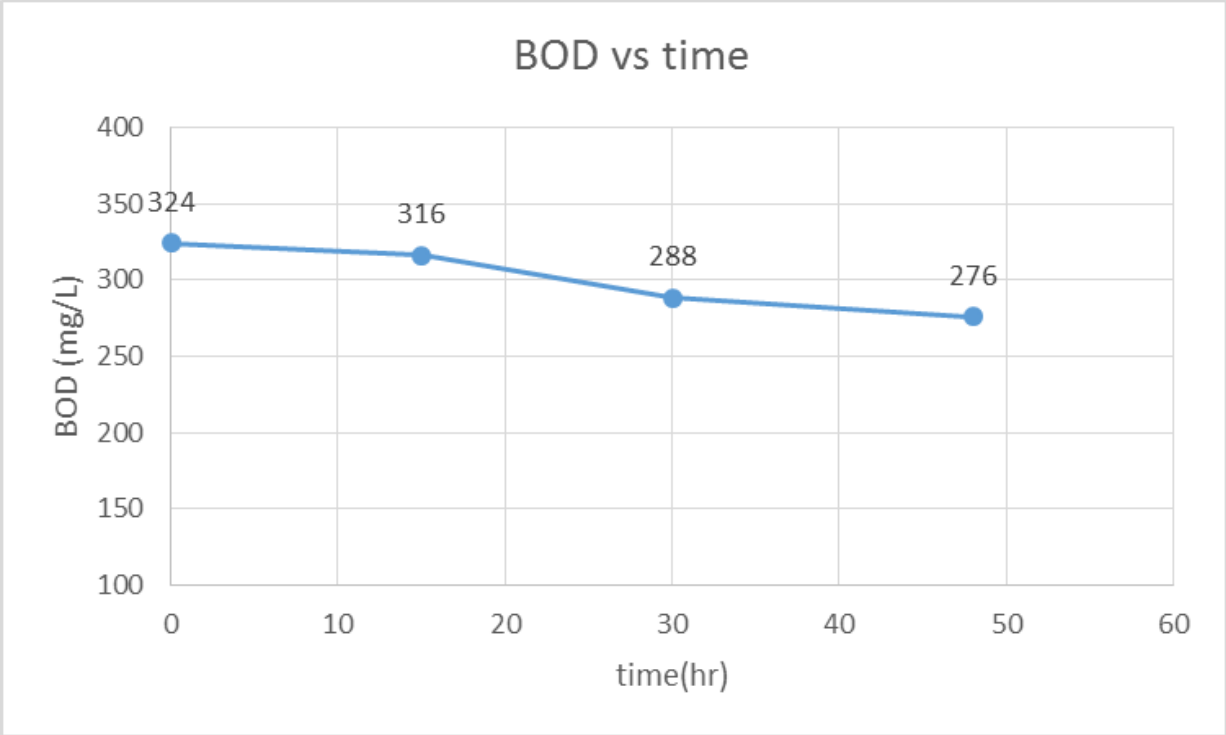

Fig. - 3.6: Variation of BOD with time during fluidization

3.6: VARIATION OF pH WITH TIME DURING FLUIDIZATION

Observed values of pH with time during fluidization is listed in TABLE 3.13 and response is plotted in Fig no: 3.7

TABLE NO. 3.13: Variation of pH with time during fluidization

Time (hr)	pH
0	7.4
15	7.4
30	7.3
48	7.3

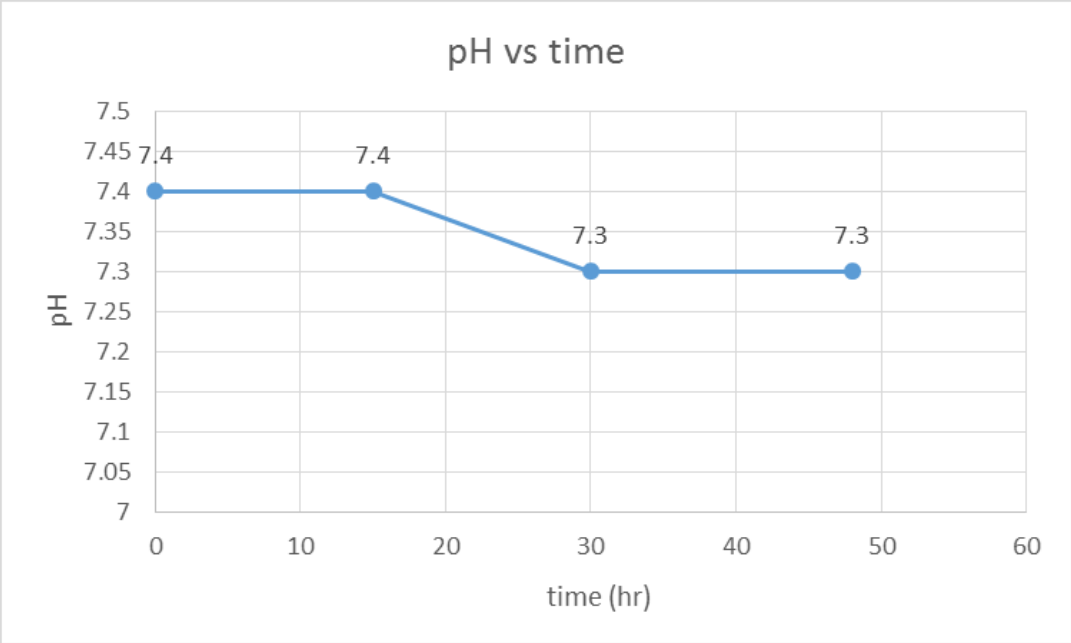

Fig. - 3.7: Variation of pH with time during fluidization

The values of the parameter decrease after treating the effluent on the inverse fluidized bed.

The following table describe the COD, BOD, pH values after the treatment and before that

The experiment was carried out at 25% v/v concentration of effluents following are the data

TABLE NO.3.14: Observed parameters before and after treatment

Sl no	Parameters	Observed value of parameter before treatment	Observed value of parameter after treatment
1	colour	Brown	Colourless
2	odour	Unpleasant	Odourless
3	COD	896 mg/L	768 mg/L
4	BOD	324 mg/L	276 mg/L
5	pH	7.4	7.3

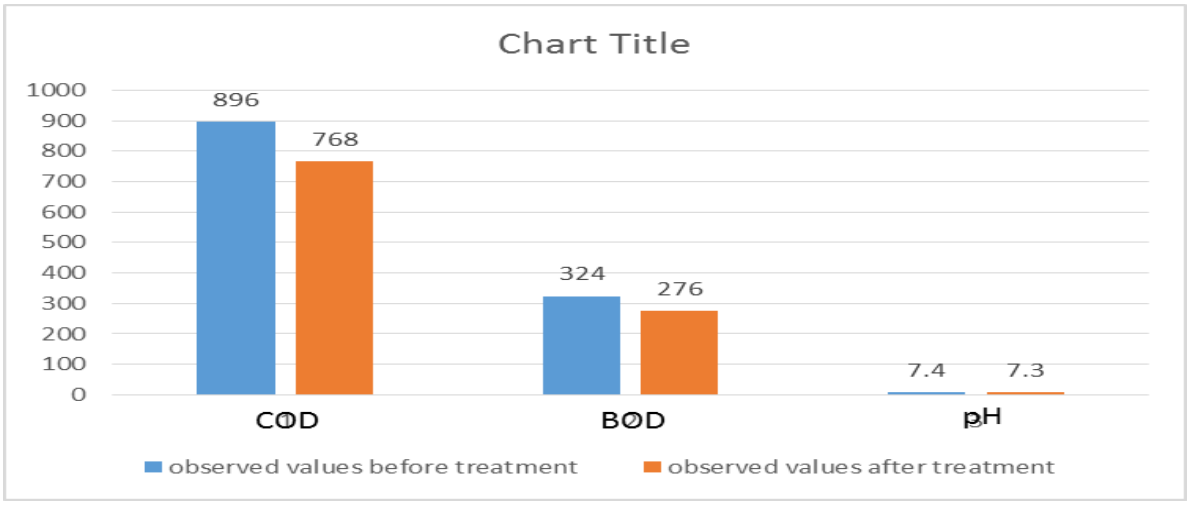

Fig:-3.8: Response of observed values before and after treatment

Effluents are categories in to different types with their BOD values following is the table from the literature regarding the types of effluent

TABLE NO. 3.15: BOD ranges

Sl no	Type of effluent	BOD ranges
1	Influent	150-400
2	Primary Effluent	60-160
3	Secondary Effluent	10-60
4	Digester Supernatant	1000-4000+
5	Industrial Wastes	100-3000+

All the processes are assumed to occur in the fluidized bed region only. The concentration of biofilm is assumed to be constant everywhere. For bio particle model, constant density was assumed, homogeneous biofilm distribution and the solid particles were also assumed to be spherical in shape. All the bed materials are assumed to be distributed evenly in the bed region. The pH of the solution in the column was maintained at suitable value (i.e. 7.3) for growth of the microorganism by which biofilm on the surface of the solid particle was developed. The solid particle used in the experiment is polypropylene whose density is less than that of effluent of sugar industry. After the microorganism grows on the surface of the polypropylene beads perfectly and produce a homogeneous biofilm the experiments were conducted by varying air flow rates. For the treatment of effluent of sugar industry we have to measure the COD, BOD and pH of the effluent at different time interval.

During the experimentation it was observed that the polypropylene particles were moving in downward direction even though the process was a batch process (liquid was not flowing from the top of the unit). The fluidization was taking place because of movement of particles in downward direction and mild upward force exerted by air from bottom. Downward movement of particles may be due to the fact that growth of biofilm on the surface of polypropylene beads making it heavier than water.

The observed data are then listed in different tables and effect of parameters on COD, BOD and pH of the effluent are shown in different plots. In table 3.4, table 3.8, table 3.9 variation of COD, BOD and pH with concentration are described and in table 3.11, 3.12, 3.13 variations of COD, BOD, and pH with time of fluidization are described. On table 3.10 observed data with standard value is compared, table 3.14 observed values before and after treatment are compared and BOD ranges of different effluents are described on table 3.15

CHAPTER 4

CONCLUSION & SCOPE

TO FUTUREWORK

4.1: CONCLUSION

In the treatment of effluent of sugar industry by inverse fluidized bed the concentration of the sample is 25% v/v with the normal water. The fluidization is 3 phase batch mode operated for 48 hour and the results are noted. The bed height is taken to be 18 cm and polypropylene beads of 6 mm dia. The pH of the sample reduced to 7.3 from 7.4 slightly reduced in the pH value. The COD of the sample is decrease to 768 from 896 in 48 hour of inverse fluidization. The BOD of the sample is decrease to 276 from 324 in 48 hour of inverse fluidization. The observed reduction in COD, BOD and pH indicate the suitability for the application of inverse fluidised bed for waste water treatment for any industry.

4.2:- SCOPE OF FUTURE WORK

Treatment of industrial effluents can be done

(i) By using different bed heights of same sized polypropylene beads.

(ii) By using different sizes of the beads.

(iii) by using different concentrations of effluent

(iv) by varying air flow rates

(v) by continuous flow of effluents

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